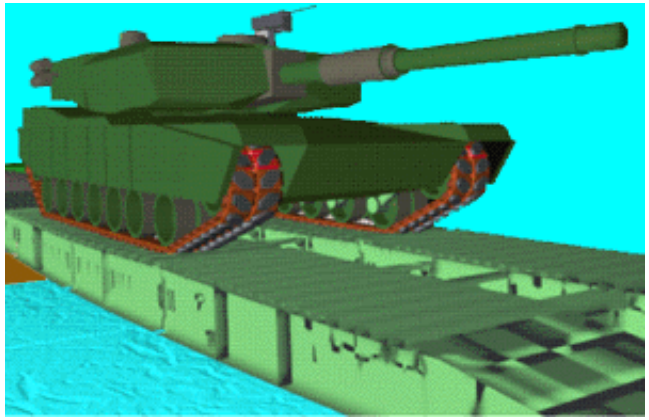
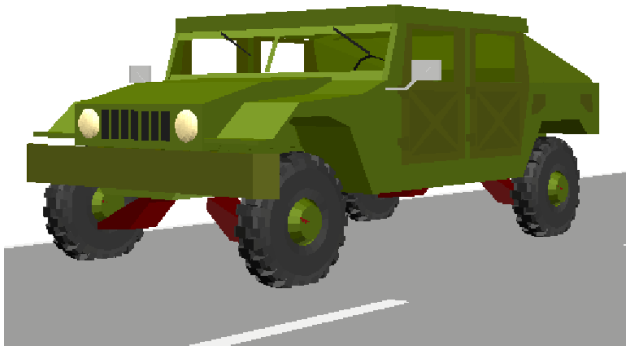
Ground Vehicle Simulation of Military Vehicles Using High Performance Computing





DoD High Performance Computing Modernization Program Users Group Conference 2001

BY

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OUTLINE

- **SIMULATION OF MILITARY VEHICLES OVERVIEW**
- **TACOM-TARDEC HPC CONFIGURATION**
- **MODELING METHODOLOGY**
- **SIMULATION-BASED ACQUISITION**
- **OTHER CASE STUDIES**
- **CONCLUSION**

SIMULATION OF MILITARY VEHICLES

WHAT IS IT?

- ANALYTICAL TESTING OF VEHICLES/SUBSYSTEMS UNDER REPEATABLE,CONTROLLED CONDITIONS
- A TOOL FOR SCREENING NEW/MODIFIED TECHNOLOGIES AND/OR COMPONENTS PRIOR TO PROTOTYPING
- PRECISE AND EFFICIENT MECHANISM FOR THE EVALUATION OF NEW SYSTEMS OR TROUBLE SHOOTING FIELDED VEHICLE PROBLEMS

WHY ARE WE DOING IT?

- COST EFFECTIVE AUGMENTATION TO FIELD TESTING
- TO ANSWER QUESTIONS THAT CANNOT BE ANSWERED BY FIELD TESTING ALONE
- TO ACCELERATE THE COMPONENT INTEGRATION PROCESS

HOW WE'RE DOING IT - ANALYTICAL EXPLORATION OF DESIGNS

SIMULATION OF MILITARY VEHICLES

MAJOR AREAS OF DYNAMIC SIMULATION

- **ON AND OFF ROAD MANEUVERABILITY AND STABILITY**
- **EMERGENCY LANE CHANGE, OBSTACLE AVOIDANCE, OBSTACLE NEGOTIATION**
- **VEHICLE MOBILITY AND RIDE QUALITY**
- **SYNERGISTIC SUBSYSTEM PERFORMANCE**
- **ERGONOMICS**
- **RELIABILITY STUDIES**
- **SUPPORT OF LABORATORY TESTING**

SIMULATION OF MILITARY VEHICLES

TYPES OF VEHICLES MODELED AND SIMULATED

- **WHEELED**
  - **- TRUCKS AND TRUCK/TRAILER COMBINATIONS**
  - **- FIFTH WHEEL/STEERED MULTI-AXLE/ ARTICULATED**
  - **- HIGH MOBILITY VEHICLES**
  - **- TOWED ARTILLERY**
- **TRACKED - LIGHT & HEAVY ARMORED COMBAT VEHICLES**

TYPES OF TERRAINS/ENVIRONMENTS SIMULATED

- **IRREGULAR SURFACE PROFILES - BUMPS, POTHOLES, RUTS, MOUNDS, SLOPES, HILLS, CHANGING SURFACE CONDITIONS**
- **IRREGULAR TRAJECTORIES - VARYING CURVATURES, STEERING AND BRAKING MANEUVERS**

TACOM-TARDEC HPC CONFIGURATION

- **HARDWARE INCLUDES (SUPPORTS PARALLEL COMPUTING):**

  - SILICON GRAPHICS, INC. (SGI) POWER CHALLENGE ARRAY: 56 MIPS R10000 PROCESSORS, 12 GB MEMORY, 500 GB ON-LINE STORAGE

  - SGI ONYX2 REALITYMONSTER: 32 MIPS R12000 PROCESSORS, 31 GB MEMORY, 430 GB ON-LINE STORAGE, 4 INFINITE REALITY 2 GRAPHICS ENGINES

  - SGI ORIGIN2000: 4 MIPS R12000 PROCESSORS, 1 GB MEMORY, 72 GB ON-LINE STORAGE

  - RELATED HARDWARE INCLUDES DISTRIBUTED HIGH-END WORKSTATIONS AND DESKTOP & BROADCAST GRAPHICS & VISUALIZATION PRODUCTION SYSTEMS

TACOM-TARDEC HPC CONFIGURATION

56-processor Silicon Graphics Power Challenge Array →

← *32-processor Silicon Graphics Onyx2 Reality Monster & 4-processor Silicon Graphics Origin2000*

MODELING METHODOLOGY: DYNAMIC ANALYSIS AND DESIGN SYSTEM (DADS)

- **GENERAL PURPOSE - USER DEFINES/DEBUGS MODELS, AUTOMATED**
- **PREPROCESSOR - USES BUILDING BLOCK APPROACH (LIBRARY)**
- **DETERMINES SPATIAL, TRANSIENT-DYNAMIC RESPONSE OF MULTIBODY MECHANICAL SYSTEMS**
- **PROVIDES RESULTS AND TIME HISTORIES OF STATE VARIABLES**
- **POST PROCESSOR - PLOTS STATES**
- **PROVIDES COMPUTER-GENERATED IMAGES FOR VISUALIZATION**

[redacted]

MODELING METHODOLOGY

CHARACTERIZATION, MODEL DEVELOPMENT AND VALIDATION

- **BOTTOM LINE—MODEL PREDICTIONS ARE NO BETTER THAN DETAIL GOING INTO THEM**
- **ACCURATE 3-DIMENSIONAL DETAIL OBTAINED FROM:**
  - CAD DRAWINGS WHEN AVAILABLE
  - HAND MEASUREMENTS WHEN NECESSARY
- **INERTIA PROPERTIES MEASURED OR CALCULATED**
- **MODELS DEBUGGED USING POST ANALYSIS AND VISUALIZATION**
- **MODELS VALIDATED AGAINST CONTROLLED FIELD TESTS**

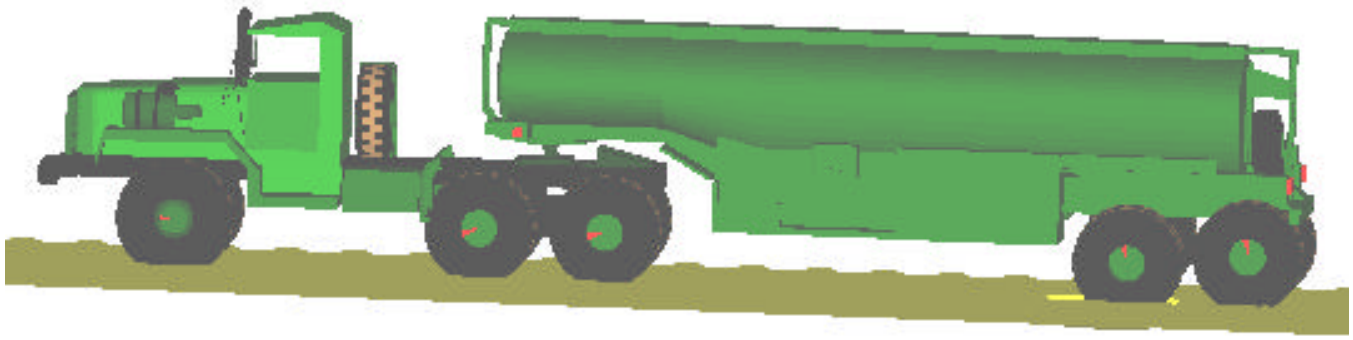
“SIMULATION-BASED ACQUISITION”

- **US ARMY ISSUES A “REQUEST FOR PROPOSAL”**
- **MODELING & SIMULATION USED TO DOWNSELECT OFFERORS**
- **HEAVIEST WEIGHT CRITERIA IN SELECTION PROCESS**
- **MINIMUM REQUIREMENTS:**

  - SIDE/ LONGITUDINAL SLOPES
  - TURNING RADIUS
  - VERTICAL STEP, RIDE QUALITY

- **PERFORMANCE ANALYSIS ON**
- **SECONDARY AND CROSS COUNTRY TERRAINS**

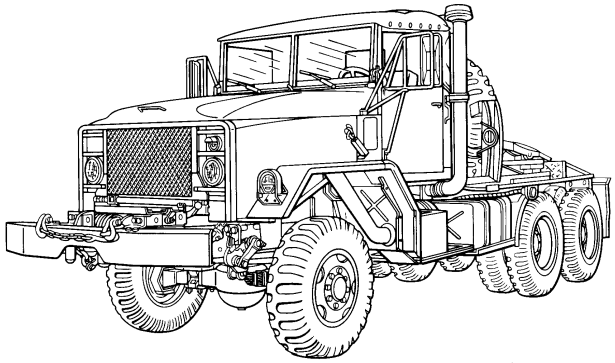
“SIMULATION-BASED ACQUISITION”
VEHICLE DESCRIPTIONS

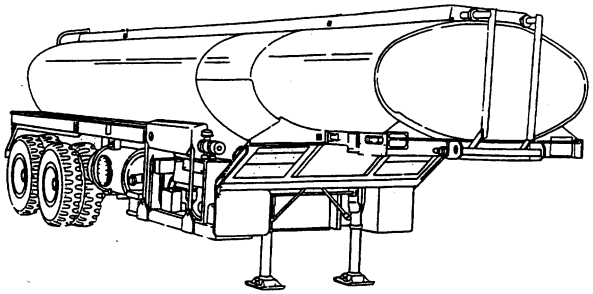


- **PRIME MOVER - 900 SERIES, 20-TON TRACTOR**
- **CTI, 11.00 X 22.5, 14-PLY TIRES, 3 SOLID-AXLES, WALKING-BEAM, LEAF SPRING SUSPENSIONS**

- **TANK-SEMITRAILER - 5000 GALLON CAPACITY**
- **11.00 X 20.00, 12-PLY TIRES**
- **SOLID AXLE**
- **LEAF SPRING SUSPENSION**
- **FIFTH-WHEEL BASED**

"SIMULATION-BASED ACQUISITION" MODELING & SIMULATION OBJECTIVES



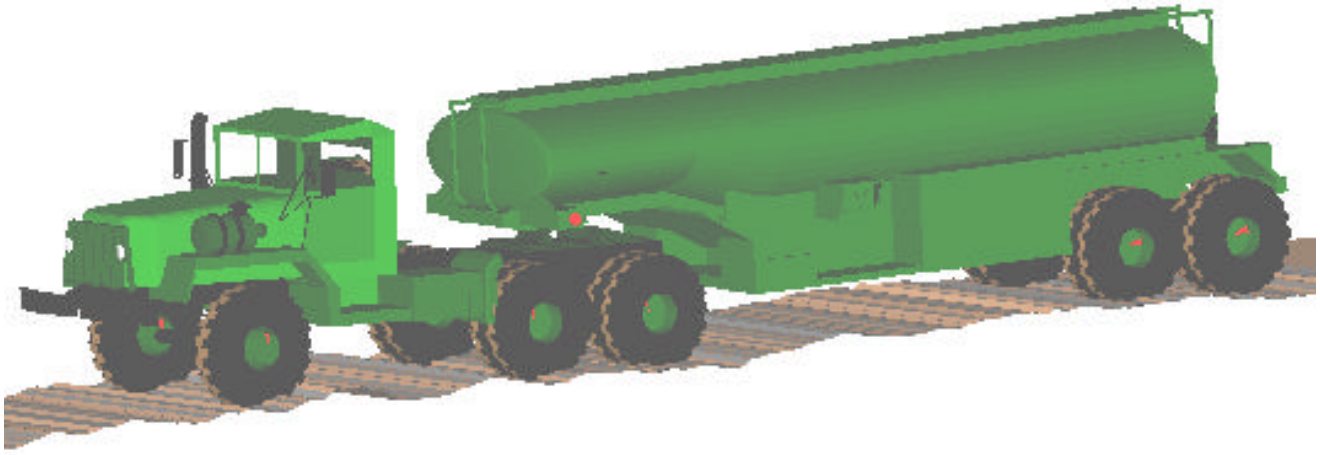


- **COLLECT REPRESENTATIVE FIELD-TEST DATA**
- **SET-UP AND VALIDATE TRACTOR/TANK-SEMI-TRAILER MODELS**
- **PERFORM SIMULATIONS TO VERIFY COMPLIANCE WITH USER-SPECIFIED PERFORMANCE REQUIREMENTS**
- **COMPARE PERFORMANCE OF BIDDER'S CONCEPTS WITH 'OLD' SYSTEMS TO LOOK FOR PERFORMANCE GAINS**
- **RANK PERFORMANCE VS REQUIRED/DESIRED PERFORMANCE REQTS**

"SIMULATION-BASED ACQUISITION"

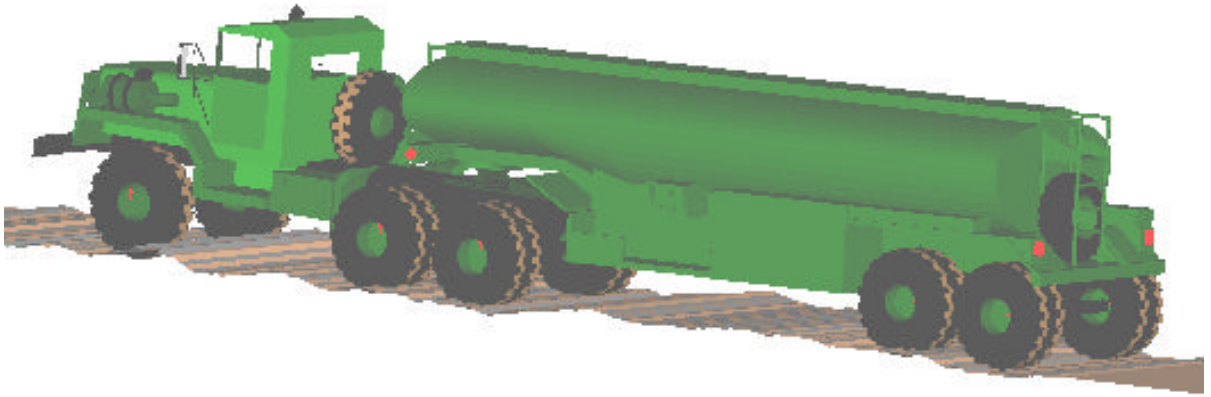
EXAMPLE OF POSSIBLE DETAIL IN HEAVY VEHICLE MODEL

- **MODEL OF A HEAVY EQUIPMENT TRANSPORT SYSTEM CARRYING 5000 GALLONS OF LIQUID**
- **TRACTOR—23 DOF, 20 BODIES, 15 JOINTS**
- **TRAILER—19 DOF, 9 BODIES, 8 JOINTS**
- **LOAD—SHIFTING MASS AND CG**



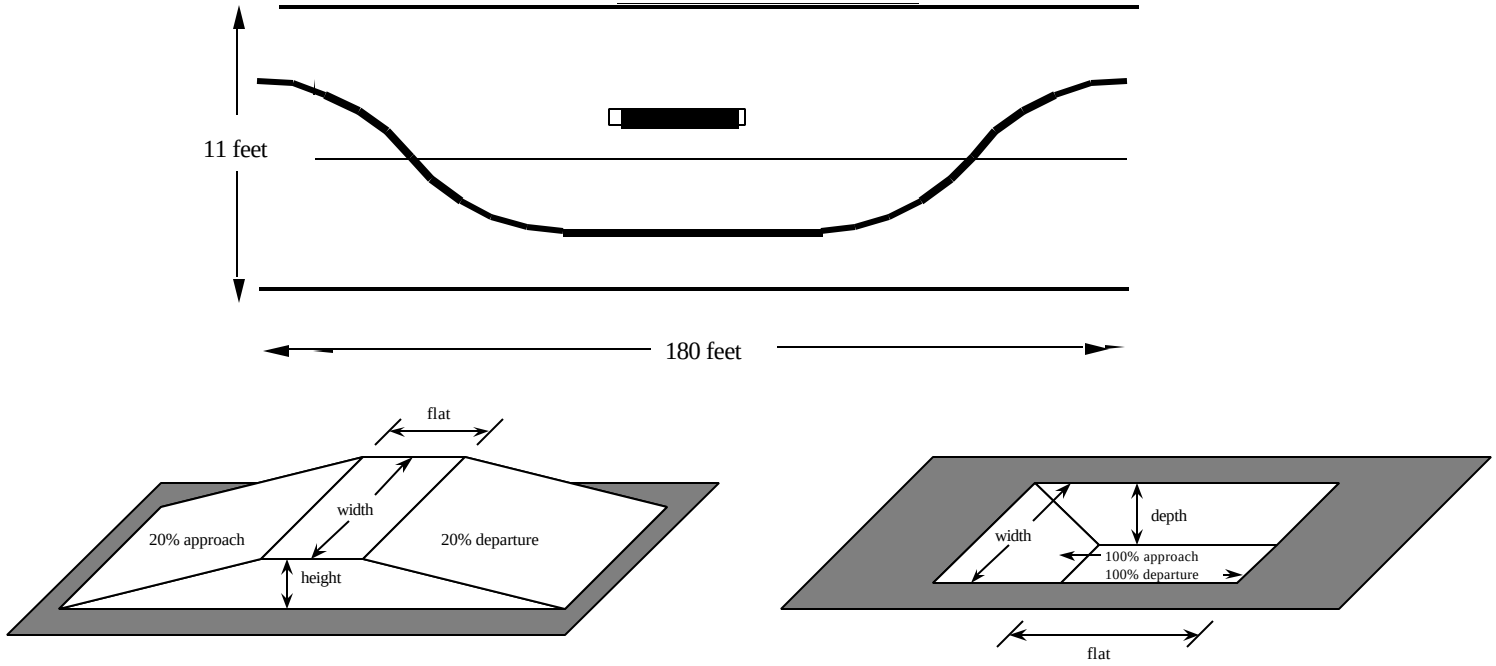
"SIMULATION-BASED ACQUISITION" MODEL DESCRIPTIONS

- **TRACTOR AND TANK-SEMITRAILER - 20 AND 9 RIGID BODIES**
- **INCORPORATES PHYSICALLY MEASURED VEHICLE PARAMETERS**
- **SPECIAL FUNCTIONS TO INCORPORATE NON-LINEAR FEATURES**
- **ACCURATE REPRESENTATION OF SUSPENSION, STEERING, AND TIRE**



"SIMULATION-BASED ACQUISITION" MODEL VALIDATION FIELD TESTS

- **LANE CHANGE, OBSTACLE AVOIDANCE, BUMPS, POTHOLES, J-TURNS, SIDE-SLOPES, AND CROSS COUNTRY TERRAINS (38 EXPERIMENTS)**
- **22 CHANNELS OF DATA COLLECTED TO MEASURE STATE VARIABLES,**
- **TRUCK SPEED AND STEERING USED AS DRIVING INPUTS TO MODELS**



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"SIMULATION-BASED ACQUISITION" MODEL VALIDATION RESULTS

- **EXTREME DISPLACEMENTS SIMILAR**
- **PEAK ROLL AND PITCH ANGLES OVER THE WIDE RANGE OF OPERATING SCENARIOS**
- **PEAK TIRE LIFT-OFF DURING LANE CHANGE MANEUVERS**
- **MAGNITUDE AND SHAPE OF THE VEHICLE DYNAMIC RESPONSE WERE ACCURATELY REPRODUCED**
- **SIMULATION MODEL IS 'ADEQUATE' FOR PREDICTING SYSTEM RESPONSE AND STABILITY**
- **MODEL READY FOR SSEB PRODUCTION RUNS**

"SIMULATION-BASED ACQUISITION" EVALUATION CRITERIA

(STAGE 1)

- **SIDE SLOPE - TRAVERSE A 30 % SIDE SLOPE W/O OVERTURNING**
- **LONG. SLOPE - ASCEND/DESCEND A 40 % LONG. SLOPE**
- **SPEED/OSCILLATION - CONFORM TO FMSCR 393.70 WHICH LIMITS TRAILER OSCILLATION**
- **TURNING - TURNING RADIUS SHALL NOT EXCEED 40 FT IN BOTH DIRECTIONS RIGHT AND LEFT**
- **VERTICAL STEP - ASCEND/DESCEND A 12 INCH VERTICAL STEP W/O INTERFERENCE**
- **RIDE QUALITY - TRAVERSE 8" HALF ROUND, @10 MPH W/ 3.0 G ACCEL.**
- **LANE CHANGE - TRAVERSE AN 11 X 90 FOOT LANE CHANGE @ 40 MPH**
- **PERFORMANCE - RELIABILITY, OPERATIONAL PROFILE, FAILURE, AND CORRECTIVE ACTION**

(STAGE 2)

- **CROSS COUNTRY - TRAVERSE BELGIAN BLOCK, MUNSON GRAVEL, PERRYMAN 1, AND CHURCHVILLE B CROSS-COUNTRY COURSES**

"SIMULATION-BASED ACQUISITION"
SIMULATION RANKING CRITERIA

PASS/FAIL:	PASS	FAIL
• SPEED/OSCILLATION	< + 3 INCHES	> + 3 INCHES
• TURNING RADIUS	< 40 FOOT RADIUS	> 40 FOOT RADIUS
• VERTICAL STEP	> 12 INCHES	< 12 INCHES

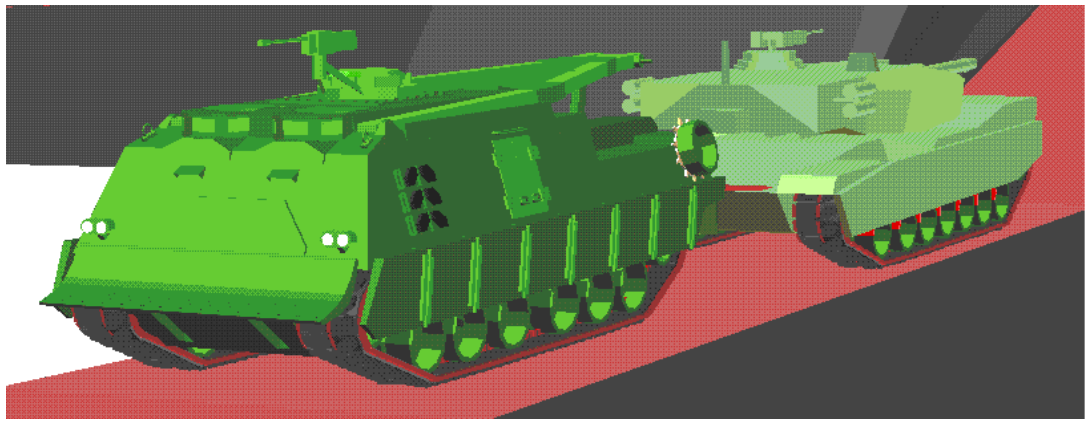
ADJECTIVAL:	DEFICIENT	ADEQUATE	GOOD	EXCELLENT
• SIDE SLOPE	<30%	30 TO 34%	35 TO 39 %	>40 %
• LONG. SLOPE	<40%	40 TO 45 %	46 TO 50%	>50 %
• 1/2-ROUND (3G)	<10	10 TO 14	15 TO 19	>20 (MPH)
• LANE CHANGE	<40	40 TO 44	45 TO 49	>50 (MPH)
• *OFF-ROAD	WORSE	SAME	EXCEEDS	FAR EXCEEDS

*** Ratings based on performance comparisons with M105A2**

Perryman 1(0.42" rms) **Belgian Block (0.69" rms)**

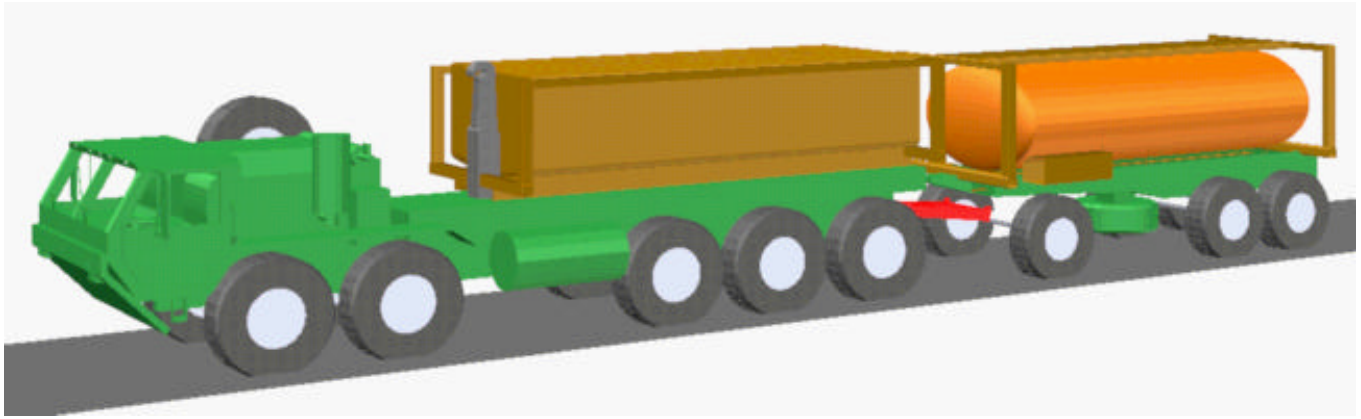
Churchville B Mild (1.77" rms) **Churchville B Rough (2.68" rms)**

IRV Towing M1 Tank Analysis



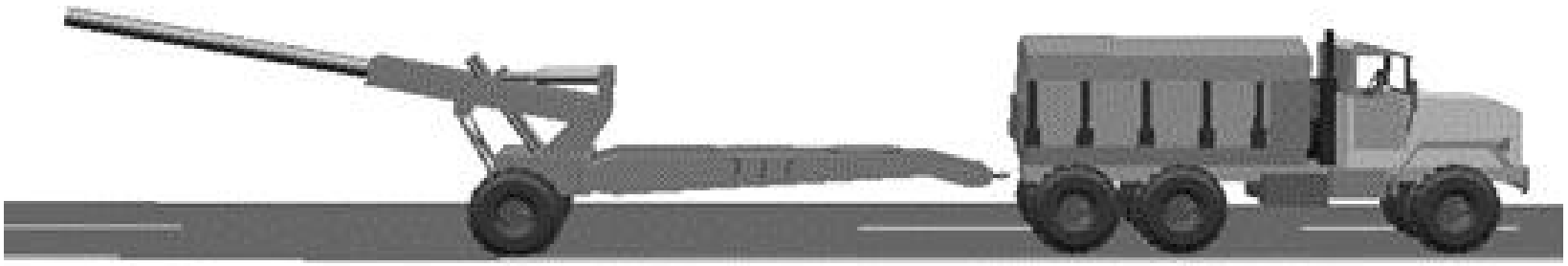
- Customer - Program Executive Officer - ASM
- Used M&S to develop and test new towbars and effective external braking mechanism
- PEO-ASM used analysis to augment field-tests and facilitate vehicle modifications to allow safe towing

Truck/Trailer Concept Variant Analysis



- Customer - PM - Heavy Tactical Vehicles
- Use M&S to evaluate transport of bulk fuel and water containers, dump body, concrete mixer, water & bituminous spreaders, 3-Con (900 & 1800 Gallon self-contained refuel/re-supply pallets), and fuel and service distribution and modules
- Proved-out feasibility of using PLS as a transporter

5-Ton/ Howitzer Stability Analysis

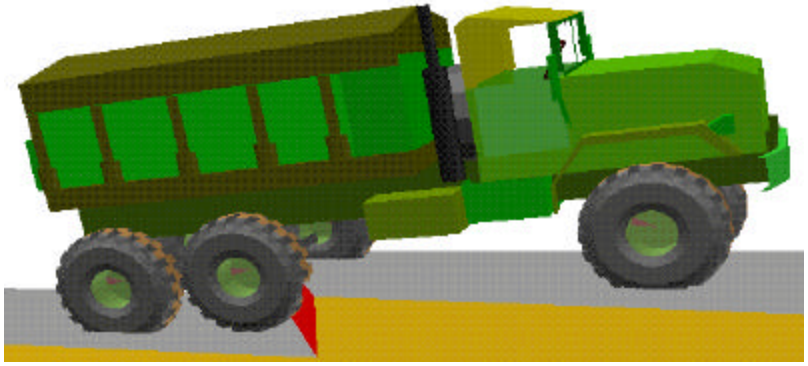


- Customer - PEO - Combat Support
- 8+ ton howitzer has de-stabilizing effect on 5-ton
- Used M&S to conduct on-road braking and steering tests
- Provided operating guidelines and payload placement criteria to make combination safer for use

M2A3 Bradley Life-cycle Support

- Customer - PEO ASM
- Virtual prototype M2A3 to evaluate special features, PIPS, configuration management changes
- Use in-house developed code to run in real-time
- Implement on DIS
- Provide data to physical simulators

Medium Tactical Truck Remanufacture Program



- Met aggressive schedule
  - 3 Months from RFP to contract award
- M&S utilized to evaluate vehicle performance
- Contractors leveraging our models to develop prototypes
- M&S will reduce field testing timelines and costs

CONCLUSIONS

"SIGNIFICANCE OF USING SIMULATION"

- **QUANTIFY LIMITS OF STABILITY, HANDLING, AND PERFORMANCE**
- **DETERMINE COMPLIANCE WITH ALL MANDATED PERF. REQTS.**
- **COST EFFECTIVE, LOW RISK, SHORT TIME FRAME FOR RESULTS**
- **AVOIDS BUILD-TEST-BREAK-FIX APPROACH**
- **PIPS AND DESIGN UPGRADES CAN BE TESTED IN SOFTWARE**
- **PROVIDE FIELD TEST INSIGHT AND GUIDELINES**
- **USE SIMULATION TO AUGMENT DECISION MAKING PROCESSES**
- **SIMULATION IS NOT A 'REPLACE ALL' FOR FIELD TESTING**